Bioaccumulation of Arsenic (As) in Fish & Toxicity of As Species

Charles O. Abernathy
HECD/OST
US EPA
Washington, DC

Topics

- Methodology
- As Levels in Aquatic Organisms
- Available Data on Freshwater Species
- Uncertainties
  - As Speciation
  - Toxicities
- Summary

Methodology for Deriving AWQC

- 1980
  - BCF (water exposure only) used to estimate bioaccumulation
- 2000*
  - For inorganics & organometallics that do not biomagnify – use Procedure 5
  - Field BAFs & Laboratory BCFs are considered equally
  - BAF = C_t / C_w

*see Methodology for Deriving AWQC for the Protection of Human Health (2000) for details on BAF framework

Does As Bioaccumulate in Fish?

- Yes, but BAFs are small relative to many other organic & organometallic PBTs (e.g., PCBs, methyl-Hg)
- BAFs for tissues of upper trophic level freshwater & marine organisms range from ~ 5 to 5000 L/kg
- As does not appear to biomagnify (increasing concentration with increasing trophic level); BAFs for TL2 $\geq$ TL3 $\geq$ TL4

As BAF Measurements in Freshwater Organisms

Trophic Level	Species Mean BAFs - Range (n)	
	Lentic	Lotic
2	10 to 19,000 (43)	7 to 3,800 (7)
3	4 to 95 (18)	2 to 1,000 (20)
4	45 to 46 (1)	6 to 270 (2)

Chemical Species of As

- Inorganic
  - Arsenite (+3)
  - Arsenate (+5)
- Organic
  - Arsenobetaine
  - Monomethyl Arsinic Acid (MMA, MSMA)
  - Dimethylarsonic Acid (DMA, Cacodylic Acid)
  - Arsenocholine
  - Arsenosugars
  - Arsenolipids

As Speciation Data for TL3 & 4 Fish

Species	Exposure Type	Inorganic	As (+3)	As (+5)	Organic
Minnow	Field	NM	-	-	0.97
Sweet Fish	Field	NM	-	-	0.88
Salmon	Field	NM	-	-	0.99

As Speciation Data for TL3 & TL4 Fish

Species	Exposure Type	Fraction of Total Arsenic			
		Inorganic	As (+3)	As (+5)	Organic
	Lab-Water				
Tilapia	(+3)	0.39	0.25	0.14	0.50
	(+5)	0.72	0.36	0.36	0.25
	MMA	0.71	0.40	0.31	0.27
	DMA	-	-	-	0.94
	Lab-Diet				
Tilapia	(+3)	0.97	0.41	0.56	0.023
	(+3)	0.85	0.41	0.44	0.037
Medaka	(+3)	1.00	0.26	0.74	0.0
Guppy	(+3)	0.15	-	-	0.84

Uncertainties

- Most speciation data for marine organisms
- As speciation:
  - 85 to ≥ 90% organic As in marine organisms
  - As species reported in freshwater organisms varies widely
  - Toxicity of As species varies greatly

Acute Toxicity of As Species

Species	LD_{50} (mg/kg)
Inorganic	
Arsenite (+3)	15 to 42*
Arsenate (+5)	20 to 200
Organic	
MMA	700 to 1800
MMA (+3; i.p.)	~30
DMA	1,200 to 2,600
Arsenocholine	6,500
Arsenobetaine	≥ 10,000

Additional Toxicological Considerations

- Toxic Moieties
  - Inorganic As (+3 & +5)
  - MMA & DMA (+3 & +5)
    - +5 reduced to +3 (more toxic form)
- However, As Species and Valence States are not usually determined

Additional Toxicological Considerations

- Arsenobetaine
  - Metabolically inert (99% excreted as parent)
  - Not cytotoxic
  - No mutagenic activity
- Arsenocholine
  - Mostly metabolized to Arsenobetaine
- Arsenicals do not concentration in human milk
- Seafood ingestion does not increase Inorganic As exposure

Summary - Bioaccumulation

- As bioaccumulates in aquatic organisms, but BAFs are generally small relative to other Persistent, Bioaccumulative Toxicants (e.g., PCBs, methymercury
- As does not appear to biomagnify (BAFs TL2 $\geq$ TL3 $\geq$ TL4)

Summary - Speciation

- Limited data indicate that both inorganic and organic As are present in freshwater organisms
- Chemical Speciation Data in Freshwater Fish is Variable
  - Lab data indicate higher % of inorganic As
  - Field data indicate higher % of organic As

Summary - Toxicity

- Valence State (+3 vs. +5) greatly affects toxicity of As
- Arsenobetaine & Arsenocholine have relatively low toxicity

Data Needs

- Data to Derive Freshwater BAFs
  - Total [As] in Water
  - Total [As] in freshwater organism tissues
  - [As Species] in freshwater organism tissues
- Are there real differences in the inorganic/organic As ratios following field vs. laboratory exposures?
- EPA would appreciate receiving any/all data you may have

Technical Summary of Information Available on the Bioaccumulation of Arsenic in Aquatic Organisms
(EPA-822-R-03-032)
December 2003

- www.epa.gov/waterscience/criteria/arsenic/tech-sum-bioacc.pdf
- Compilation of data available in the literature (and calculated Species Mean BAFs) for consideration in developing or revising Water Quality Standards
  - Use aquatic species BAFs appropriate for Regional, State or Tribal consumption patterns.
- Does not provide National BAFs

- Dr. Tala Henry
  Phone: 202-566-1323
  Email: henry.tala@epa.gov
- Dr. Charles Abernathy
  Phone: 202-566-1084
  Email: abernathy.charles@epa.gov

- EPA's *Technical Summary of Information Available on the Bioaccumulation of Arsenic in Aquatic Organisms* (EPA-822-R-03-032)
  www.epa.gov/waterscience/criteria/arsenic/tech-sum-bioacc.pdf